A Layered Approach to Packet Based Instrumentation

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Abstract

Networks are becoming a part of everyday life. They are in our offices, homes, cars, and the basis for the Internet. The ground processing side of T&E have used networks in various forms for years to direct the incoming test data to the many project engineer stations. These interfaces are becoming relatively inexpensive due to the proliferation of networks. We are now seeing networks appear in the vehicular data acquisition arena. To take advantage of what networks have to offer, we need to view the data system as a communications network.

As a communications network, the instrumentation system must be segregated into individual layers in a logical fashion. Each layer operates independently and can be upgraded or replaced without regard or effect to the other layers. This layered model can be used as a blueprint to take advantage of commercial network architectures. It will easily allow new technology insertion in key areas without affecting the rest of the system. The Navy and the Air Force see this approach as a key component of acquisition reform and have established a comprehensive road map to achieve this goal.

Background

There have been two major paradigm shifts involving the design of instrumentation systems over the last 30 years. The first shift was concerned with how the data was multiplexed for acquisition. The early instrumentation systems multiplexed parameters within the frequency domain – frequency division multiplexing (FDM). FDM channels provide fairly fixed bandwidths per channel limiting the number of parameters that could be multiplexed at one time. Most current systems use time division multiplexing (TDM). TDM uses the time domain to multiplex parameters into a single data stream. TDM allows more parameters to be recorded and/or transmitted by allowing more flexibility in assigning bandwidth per channel. For many systems with large numbers of low frequency parameters, this was a real advantage. Although not a function of TDM, the introduction of digital technology is usually associated within this timeframe. Since FDM is straight forward and easy to use in small systems, it has not died out completely (reference figure 1).

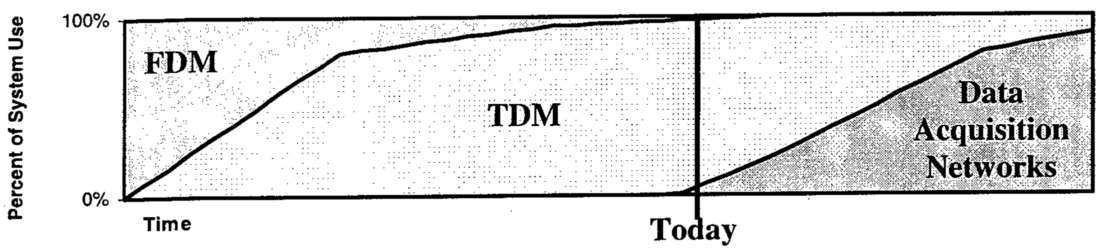

Figure 1 Evolution of Data Systems

The next major shift distributed the signal conditioning and modulation closer to the signal source. (reference Figures 2 and 3) A distributed system was easier to install in space constrained test articles by wiring signal sources to a relatively close remote unit. The remote unit communicated back to the system controller via a communications bus. The controller to remote unit communication introduced a higher level of complexity than was seen with previous systems. As distributed systems became more prevalent, system designers wanted a unit from one system to work within another system. The Common Airborne Instrumentation System (CAIS) set out to fix that problem by establishing a common hardware set that would be built by multiple manufacturers. During execution of the CAIS program, acquisition reform resulted discarding the build to print technical data package in favor of a CAIS Bus Interface Control Document (ICD). The CAIS Bus ICD was a solid step towards one of the primary goals of the CAIS program – vendor interoperability.

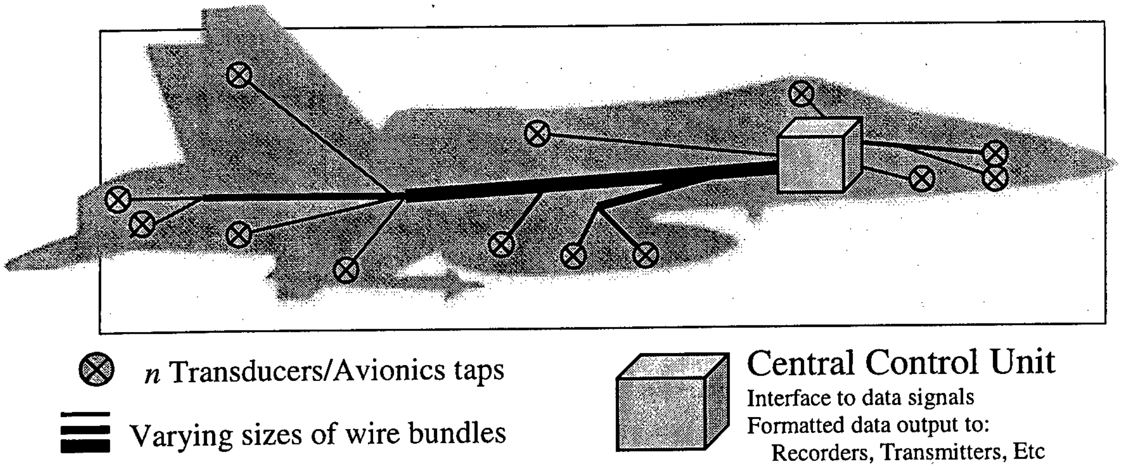

Figure 2 Centralized Data System

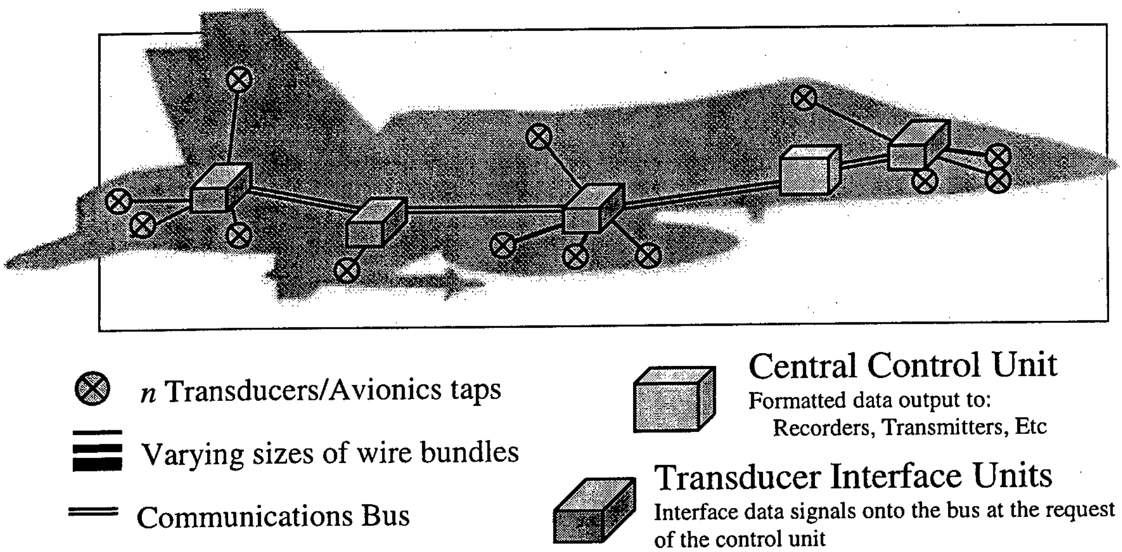

Figure 3 Distributed Data System

As the CAIS Bus ICD was completed, a couple of major acquisition programs had instrumentation requirements that exceeded the capacity of the CAIS system. Looking at the data system capacity of one program over a number of years shows an exponential requirement (reference Figure 4). Projecting this growth rate to the near future shows a need for a high capacity data bus. The Next Generation Instrumentation Bus (NexGenBus) was started to help meet this need. An unexpected outcome of the NexGenBus research of fast commercial communications busses showed them all to be network compatible. The Advanced Range Telemetry (ARTM) program looked at alternate telemetry methods and discovered that packetized telemetry was a viable

alternative to the way we currently do business. By many accounts, we are now on the verge of a third technology shift – Data Acquisition Networks.

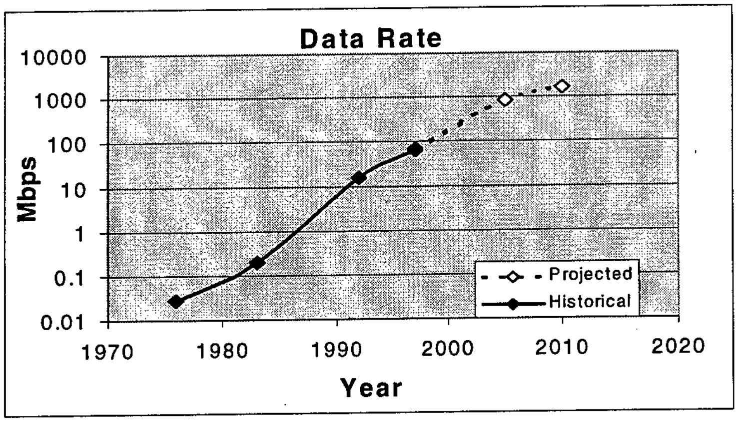

Figure 4 Historical and Projected Data Rates

Data Acquisition Networks

The Next Generation Instrumentation Bus (NexGenBus) program was established to find a fast commercial communications bus that could be used as a test instrumentation bus. When the list of fast commercial busses was compiled, it was discovered that all of the busses were networked based. This realization was a source of both concern and delight. The concern was the complexity of the bus and the systems that would communicate across it. Traditionally, test article instrumentation has been tightly coupled application specific designs. Instrumentation engineers learned how to design an installation based on one of a few systems. The broad application of network based systems represents a huge learning curve to the vast majority of users. At the same time, there is a feeling of delight. We have all used email and the Internet at one time or another. Enabling the test instrumentation with similar connectivity across the test range and throughout the country was attractive. The ability to connect the test article (e.g. an aircraft on the flight line) on one side of the test range to the network and trouble-shoot or verify software loads from the other side is just the tip of what network connectivity will bring.

Layered Models

While researching busses during the NexGenBus project, the one thing found to be common among the different standards was a layered communication model. Unfortunately they did not all use the same model, but the individual models use the same basic model as a starting point. It is not important to understand each of these individual models. It is important to understand a basic reference model. The basic reference model that is most notable is the Open System Interconnection (OSI) Basic Reference Model (also called the 7 layer communications model). There two major reasons the OSI model should be considered. First, it teaches the concept of independence of layers. Second, even though it is hardly ever called out directly in a standard or communication system, it is the standard to which others are compared and discussed.

There are 7 layers in the OSI model. The top or 7th layer is closest to the user and application software that resides on your PC (e.g. MS Word). The lowest or 1st layer is the actual physical cable or RF signal that moves the data from one node to another. The layers between the top and the bottom are intermediate steps the system takes to ensure the data gets where it's supposed to go. What makes the OSI model so useful is that each layer is independent of the other layers. The model was created such that the interfaces are standardized so a layer can be changed without significantly affecting the rest of the stack. The OSI layers as defined in the ISO standard are listed below.

Layer 7:	**APPLICATION**	The highest layer in the OSI reference model. This layer provides the sole means for an application process to access the OSI environment.
Layer 6:	**PRESENTATION**	The Presentation Layer provides for common representation of the data transferred between application-entities.
Layer 5:	**SESSION**	The Session Layer provides the means necessary for cooperating presentation-entities to organize and synchronize their dialogue and to manage their data exchange.
Layer 4:	**TRANSPORT**	The transport-service provides transparent transfer of data between session entities and relieves them from any concern of the details of the data transfer.
Layer 3:	**NETWORK**	The Network Layer provides the functional and procedural means for transmission among transport-entities. It therefore relieves the transport-entities of routing and relay considerations.
Layer 2:	**DATA LINK**	The Data Link Layer provides the functional and procedural means for the establishment, maintenance, and release of data link connections. The Data Link Layer detects and possibly corrects errors which may occur in the Physical Layer.
Layer 1:	**PHYSICAL**	The Physical Layer provides the mechanical, electrical, functional and procedural means to activate, maintain, and de-activate physical connections for bit transmission between data-link-entities.

Information being transferred from a software application in one computer system to a software application in another must pass through each of the OSI layers. To send a sound file from one computer to another, the user directs the software to send the file. The file is passed to the Application Layer that may add control information to the file and pass it to the Presentation Layer. The Presentation Layer treats the original file plus the Application Layer control information as data. Each layer will perform work on the data being passed from the previous layer according to its protocol. Once down at the Physical Layer, the information is placed on the physical network medium and sent to the other computer. The Physical Layer of the second computer removes the data from the physical medium and passes the data up the stack to the next layer. This continues until the Application Layer passes the data to the application software where the user can access the sound file.

The real power of this can be seen in an office environment. When the local area network (LAN) is upgraded from Ethernet (10 Mbps) to Fast Ethernet (100 Mbps), only the lowest level needs to be changed--the transmitter and receiver circuitry as well as the actual cable and connectors. The rest of the communication stack can be left as is. The user may notice the faster transfer rate but his or her interface stayed the same. In reality,

things aren't necessarily this clean but it does illustrate the point. Another power of this concept is the ability to link dissimilar networks through bridges and routers (reference figure 5) or to intermix physical media within the same network.

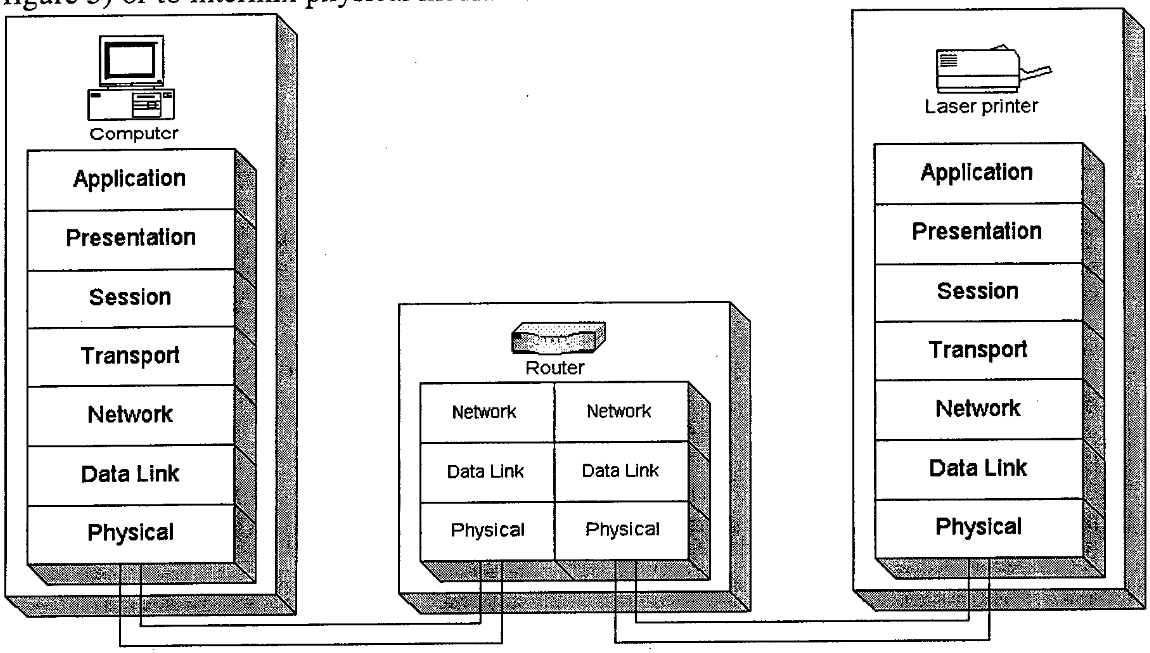

Figure 5 Networks connected across a router

A Layered Approach

There are two things that can be assured within the framework of this paper. One is the Department of Defense no longer drives the data acquisition market. The other is we are living in a networked world. As a result of these two "truths", we need to embrace the network revolution and do so in a way that is compatible to the commercial network market. This is not to say we should start blindly flying laptops with data acquisition cards and wireless Ethernet connections. What this does mean is we need to choose our "fights" carefully. One of the first steps we must take towards embracing the commercial network world is to adopt their lexicon. The telemetry community is no longer isolated from other markets due to writing their own specifications. There are several examples where the telemetry community is adopting/adapting commercial standards in part or in whole. Without using a common dictionary from the beginning, the resultant standards are ambiguous thus not useful.

The second and more important step is to not take this shift to networks lightly. If we want to benefit from the telecommunications market, we must structure our approach appropriately. As new cables, interfaces, and protocols are developed, we want the choice of adopting them in the same manner as any network administrator. A layered reference model is needed to take advantage of what the COTS market has to offer. As usual, it's not quite as easy as it seems. Simply adopting a reference model is not

enough. We need a reference model that will meet our needs given the way we do business now and the way we want to do business in the future. The only way to get a model that meets our needs is to develop one. The only way to develop one is to understand the business you want to model **and** understand how to construct a model. Many in the Telemetry community have solid understandings of how we are currently operating. Some of the Telemetry community have strong conceptions of how we can benefit from network technology. Few in the Telemetry community know how to combine our understandings and conceptions into a comprehensive model that can guide the development and application of new technology. If we want to maximize the cost and technology benefits of the Telecommunications market, we need to start putting our energies into understanding and developing a layered reference model.

What we are doing now

There has been a lot of momentum toward the idea of network based data acquisition over the past couple of years. A vocal consensus seems to have been reached that networks are indeed coming. The Range Commanders Council (RCC) has several tasks related to network compatibility of which some are funded through the Office of the Secretary of Defense (OSD). These tasks and projects have done a pretty good job of spreading the word about network-based initiatives. Many vendors have listened and are including network capable products in their brochures and demonstrations. Unfortunately everyone is working to his or her own conceptions. We need to communicate a common model so everyone will be driving toward the same solution.

There are several venues where network issues are starting to be addressed – especially at a systems level. The Range Commanders Council (RCC) have a conceptual idea of how network connectivity could benefit the telemetry market (reference figure 6). This is far from complete, but it is a start. Based on this understanding a Networks part will be added to the IRIG 106 Telemetry Standards. The Joint Data Acquisition Networks Standard (JDANS) (a proposed OSD program to begin in FY02), is planning to attack this problem in detail. To help precipitate these ideas, a joint DoD/NASA task force is being put together to leverage knowledge and requirements between the two agencies.

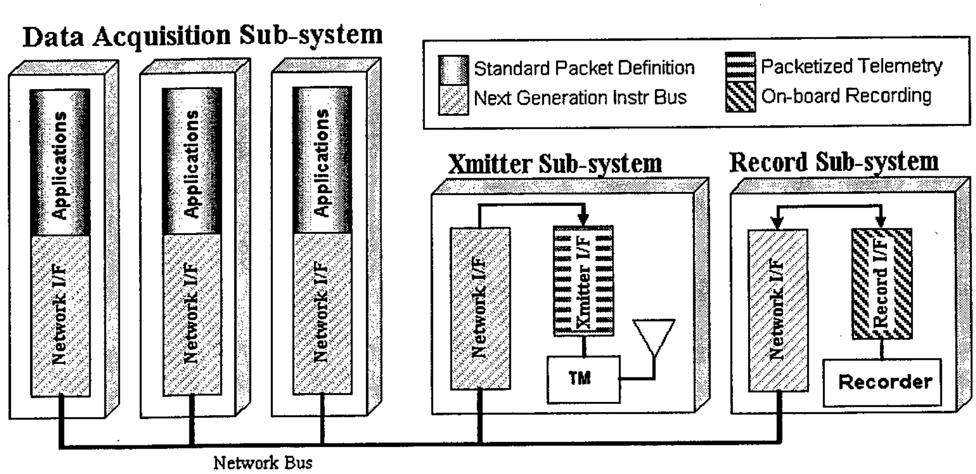

Figure 6 Data Acquisition Network Concept

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